system. The system 10 comprises a backlit LCD modified with a novel, switchable backlighting panel formed of a backlight 12, micro-collimator array 14, a first hologram 16, a second hologram 18 and a standard LCD 20.

When assembled and in use, the backlight 12 transmits light through the mirco-collimator array 14. The micro-collimator array 14 projects the collimated light toward the first waveguide hologram 16 at a predetermined angle, preferably zero degrees. The first hologram 16 then diffracts the light with an angle greater than the critical angle, preferably 45 degrees, and disperses it into various wavelengths. The first and second holographic recordings within the second waveguide hologram 18 then deflect the light to corresponding first and second viewing zones before exiting through the corresponding odd and even pixels of the LCD display 20. Each element of the system 10 will be discussed in greater detail in the following sections.

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2. The 3-D HLCD Apparatus

As shown in figures 2 and 2A, the system comprises a backlight 12, a micro-collimator array 14, a first hologram 16, a second hologram 18 and a standard LCD 20 containing pixels 21.

<u>A. The Backlight</u>

The backlight 12 may be a conventional collimated light. For example, the light may be a compact, low power white light collimated illumination source. The light may be formed through various methods including using a low power metal halide lamp with a Fresnel lens having a short focal length.

B. The Micro-Collimator Array and Method of Making

The micro-collimator array 14 may be used to collimate the backlight source if it is not collimated (i.e. diffused). The pinhole formed at the focal point of each micro-lens concentrates and collimates the light. The micro-collimator array 14 is formed through the following process as shown in Figure 3.

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An appropriate commercially available micro-lens master 22 is selected. A rubber negative 24 of the master is formed of rubber or other suitable material. A substrate 26 is coated with UV curable epoxy 28 preferably having an index of refraction between 1.48 and 1.65. The rubber negative 24 is then pressed into the epoxy 28 to form the micro-lenses 22 of the micro-collimated array 14. As the rubber negative 24 is pressed into the epoxy 28, UV light is directed through the epoxy coated substrate 26 to cure the epoxy 28. After the rubber negative 24 is removed, the substrate side of the micro-collimator array 14 is coated with a mixture of black dye containing Shipley positive photoresist composition. UV light is then directed through each micro-lens 22. The curvature of each micro-lens 22 focuses the UV light on focal points 30 along the substrate 26, softening the substrate at each focal point 30. An etching solution is then applied to the substrate 26, forming the pinholes within the micro-collimator array 14.

C. The First Hologram and Method of Making

Referring now to figure 4, the first hologram 16 is used to direct the light to the second hologram at a predetermined angle preferably between 45 - 50 degrees off horizontal (i.e., greater than the angle of reflection) which spreads the light into red, green

and blue spectral images. The first hologram is formed through a conventional two-beam recording process. More specifically, a holographic plate substrate 32 is coated with a photosensitive emulsion 34 such as silver halide. A diffused object beam and a collimated reference beam pass through the substrate 32 and into the emulsion 34 to record a hologram that disperses light between 45-50 degrees off horizontal. The resulting hologram disperses the light projected through the micro-collimator array 14 into separate red, green and blue spectral images.

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D. The Second Hologram and Method of Making

The second hologram 18, as shown in figure 5, comprises two separate interlaced holographic recordings. One recording corresponds to a right visual field and the other corresponds to a left visual field. When viewed, the final hologram produces alternating right and left holographic recordings that correspond directly to pixels in the LCD as illustrated in figure 6 and create a three-dimensional effect. Each alternating right and left recording is a predetermined width. This width is equal to the width of a standard LCD pixel, preferably 200 microns.

The second hologram 18 is a right-left interlaced hologram master formed through the following process. As shown in figure 5, a holographic plate or substrate 36 is coated with a photosensitive emulsion to form an emulsion layer 38, preferably silver halide. The coated substrate 36 is then mounted onto a gray glass plate holder 40 so that the emulsion layer 38 is facing away from the gray glass plate holder 40. The exposed side of the emulsion layer is then coated with an indexing fluid 44 such as ISOPAR ®.

1. The Photolithographic Mask

A photolithographic mask 44 is placed over the emulsion layer 38 and coated with indexing fluid 46 prior to recording. The mask 44 provides a series of equally spaced lines. Each line having a width equal to the width of a standard LCD pixel, preferably between 200 to 300 microns. For example, if the odd number lines are black 48 and the even number lines are clear 50, the odd number lines act as a mask, blocking holographic recording under the odd numbered lines of the mask 44.

2. View Region Mask

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It is well known that humans perceive three-dimensions because the information received by the right eye is slightly different than the information received by the left eye. The separation of approximately 2.5 inches between the right and left eyes results in these perceived differences which converge to provide depth cues that create a three-dimensional effect. This concept is mimicked through the use of the view region mask 52 during the holographic recording process as shown in figure 5.

A view region mask diffuser 52 is used to block out either the right visual field or the left visual field during a holographic recording. The view region mask diffuser 52 comprises a substrate 54 and a view region mask 56.

The view region mask 56 provides a series of blacked out regions 58. For example, each blacked out region 58 may be 2.5 inches wide and 2.5 inches apart from the next blacked out region 58. During the recording process, the view region mask 56 is placed in

the path of the object beam. The blacked out region 58 will block out either the right or the left half of the object beam.

The view region mask 56 is used in conjunction with the photolithographic mask 46 to create a first holographic recording and a second holographic recording which interlace to create separate right and left visual fields.

Referring now to figure 6 and figure 7, both the photolithographic mask 44 and the view region mask 56 have a first position and a second position. During the first holographic recording, both the photolithographic mask 44 and the view region mask 56 must be in a first position. Both the photolithographic mask 44 and the view region mask 56 must then be shifted into their second position before the commencement of the second holographic recording.

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For example, if the photolithographic mask 44 masks the area corresponding to the odd number pixels of the LCD, and the view region mask 56 blocks the right viewing region during the formation of the first holographic recording, the photolithographic mask 44 must mask the area corresponding to the even numbered pixels of the LCD and, the view region mask 56 must block the left viewing region during the formation of the second holographic recording.

The holographic recordings are formed through a two-beam recording process as shown in figure 5. The first holographic recording is formed by passing the object beam through the view region mask 56 positioned at a distance equal to the systems desired playback distance and then through the photolithographic mask 44. The reference beam

passes through the photolithographic mask 44 at an angle equal to the reference angle used to record the first hologram, preferably between 45-50 degrees off horizontal. The photolithographic mask 44 and the view region mask 56 are then shifted from the first position to the second and the recording is repeated to form the second holographic recording.

The first holographic recording creates a plurality of holograms of a predetermined width, which are separated by blank spaces of the same predetermined width. The second holographic recording creates a plurality of holograms with slits that fill in the blank spaces present after the first holographic recording.

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Copies of the right-left interlaced hologram master 18 are then made through contact copying wherein the right-left interlaced hologram master 18 is copied with conventional procedure utilizing a 45 degree reference laser beam having a wavelength of 514 nanometers.

More specifically, as shown in figure 8, a contact copy 66 of the right-left interlaced hologram is formed through the following process. A holographic plate 60 coated with a photosensitive emulsion 62, such as silver halide is loaded onto a gray glass plate holder 40 with the photosensitive emulsion 62 in contact with the gray glass plate 40. A glass spacer 64 is positioned over the holographic plate 60. The spacer 64 is preferably 1mm thick. The right-left interlaced hologram master 18 is then positioned over the glass spacer 64 so that the emulsion coated side of the right-left interlaced hologram master 18 is in contact with the spacer 64. The coated holographic plate 60, the spacer 64 and the right-

left interlaced hologram master 18 are indexed so that the emulsion coating on the holographic plate and the emulsion layer on the master are separated by a distance equal to the thickness of the LCD substrate, preferably 1mm. The contact copy 66 is then recorded by passing a single reference beam through the master 18, spacer 64, holographic plate 60, and photosensitive emulsion layer 62 at a predetermined angle, preferably 45 degrees, for a predetermined exposure time. The contact copy 66 is then developed through photochemical processing.

B1 There are virtually innumerable uses for the present invention, all of which need not be detailed here. All the disclosed embodiments can be practiced without undue experimentation.

Although the best mode contemplated by the inventors of carrying out the present invention is disclosed above, practice of the present invention is not limited thereto. It will be manifest that various additions, modifications and rearrangements of the features of the present invention may be made without deviating from the spirit and scope of the underlying inventive concept. For example, the individual components need not be fabricated from the disclosed materials, but could be fabricated from virtually any suitable materials. Further, all the disclosed features of each disclosed embodiment can be combined with, or substituted for, the disclosed features of every other disclosed embodiment except where such features are mutually exclusive.